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Humus in New Hampshire Soils

Potatoes on Clay Loam. Variety Plots.

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DURHAM, N. H.

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HUMUS IN NEW HAMPSHIRE SOILS.

BY FRED W. MORSE.

Introduction.

In New Hampshire there are few large continuous areas of any single type of soil, but on the contrary, within the limits of almost every farm, the soil expert would find it necessary to classify the soils under several different types. By a thorough investigation of those of the New Hampshire College farm, it is possible to determine their properties and the relations between the soils and crop production. Thus some fundamental principles may be brought out which will be applicable to similar soils on all farms, and improvements in farm practice can be developed.

Conditions of soil and surface change sharply within short distances, therefore each farmer must observe carefully for himself the character of his soils, the fertilizers required and the crops which are best suited to his land. These observations will need to be based in part on field experiments with fertilizers, but largely on comparisons with the soils and surface of other farms. A farm well suited to hay production does not usually have the types of soil adapted to early vegetables.

Some soils are of considerable depth while others are shallow. Some soils are classified by practical men as "strong," thereby meaning that they retain manures or fertilizers, while others are called "leachy," since heavy dressing with manures does not seem to last as in the "strong" soils. One broad generalization may be made between these two types of soils. The "leachy" soils in our state are usually underlain by gravel and sand, while the "strong" soils have a clay subsoil. The durability of the two classes will depend in part on the depth of the true soil, in part on the depth to the gravel or ledge, and in part on the drainage.

It can be easily reasoned out that the thin soil must be the most quickly exhausted and require the most systematic feeding with fertilizers, and if this soil is subject to easy drainage, soluble chemicals in excess of plant needs will wash out and be lost, since there is seldom much opportunity for capillary attraction to bring up water through sand or gravel.

Loams overlying clay are in a wholly different situation. Drainage is slow, capillary attraction is strong and soluble elements of fertility remain in place until the plants can make use of them. hence the term "strong."

Humus.

One of the most important constituents of a soil is the brown or black vegetable matter, called humus, a substance which has always received much attention from agricultural chemists. It is produced during the decay of vegetable matter, in the presence of moisture, and is a mixture of compounds, some of which are known, while some, perhaps many, are not yet identified. Humus may thus have a variety of properties due to its complex character. It is usually obtained in analysis by extracting it from the soil with strong ammonia water. Many views have been held with regard to its relations to crop production and opinions have changed from period to period as new facts have been observed and new truths worked out. But throughout the century or more of study and argument, humus has always been recognized as one of the leading factors in making a fertile soil. It is the object of this bulletin to show how much humus there is in our soils and how to maintain it as an effective constituent.

Types of Soil Studied.

Three different types of soils on the college farm have been examined and they are classified by Professor Taylor as clay, clay loam and sandy loam, respectively. The sandy loam forms only a small part of the farm and exists in low rolling ridges or knolls formed by the water of the glacial period. Borings to the depth of thirty inches show the loam to be underlain by a

fine sand. They are the least productive portions of the farm for hay and suffer from drought.

Clay forms the largest part of the farm when the subsoils are considered and is the top soil on the lowest levels. It is the boulder clay formed by the glacial period and is very compact. The top soil when moist is very dark brown in color, but dries to a dark gray tint. Tillage can be successfully done only when the moisture conditions are favorable, since too much water causes the soil to puddle while too little results in large clods that will not pulverize.

The clay loams are on the slopes which lie between the low land and upland. On the latter the soil is classified as a stony loam, from the small boulders and irregular fragments of rocks which occur in it. The subsoils of this type are of clay, which is about as compact as that in the low land.

For the chemical studies on these soils, the principal samples were taken from grass land which had been cropped for three or more seasons, since such soils would more nearly represent the character of similar soils on other farms.

The samples were taken from different fields on the various types of soil by making borings with an auger to the subsoil. A depth of eight inches accomplished this on the loam, while six inches reached it in the clay soil. Since the sandy loams formed a relatively small part of the area in grass, only one sample was taken of this type. Ten samples represented the clay loam, four of which were from the lower portions of the slopes and six from the upper. Six samples were taken on the clay soil of the low meadows, selected where the drains were efficient in removing excess of water.

Amount of Humus in the Soils.

The percentages of humus found in these three types of soil are given in the following table:

Percentage of Humus in Grass Land.

Sandy loam,	1.81
Clay loam, upper slopes,	2.10 to 2.57, Average 2.31
Clay loam, lower slopes,	2.81 to 3.09, Average 2.93
Clay,	3.33 to 5.37, Average 4.50

Fig. 1.—Sanford Corn and Soy Beans on Clay Soil. Trees in the middle distance on Sandy Loam. Clay Loam on the slope at the right.

The clay soils contain the most humus and the sandy loam the least, which is in accordance with the principles of humus formation, since moisture and lack of air favors the transformation of vegetable matter into humus and the preservation of the latter, as shown in peat beds, while the drier, more open character of the sandy loam admits air freely to oxidize and destroy the humus.

The clay loams are not quite midway between the sandy loam and the clay, since they average 2.56 per cent of humus for all.

Besides these samples of our farm soils, a few lots which were received from time to time from other farms were also analyzed for humus, with the following results: Four loams contained from 2.12 per cent to 2.65 per cent, with an average of 2.32 per cent; two sandy loams contained 1.52 per cent and 1.57 per cent, respectively, and one dark loam contained 3.30 per cent.

From these results it is reasonable to infer that the soils of our old grass fields seldom contain more than 3 per cent of humus on the uplands, but may contain 4.50 per cent on our low meadows. Hilgard[1] says: "In ordinary cultivated lands it rarely exceeds five per cent, and very commonly falls below three per cent, even in the humid regions."

This is sufficient to show that our soils are not so worn out as is often claimed, but compare favorably with other sections. The average for Minnesota[2] soils has been found to be 3.66 per cent and in North Dakota[3] to be 4.77 per cent.

The Value of Humus.

The effects of humus on soils are both physical and chemical. Its physical effects are due in part to its remarkably porous structure which not only lightens the texture of soils but also increases the absorptive power of soils for water and the plant food dissolved in it. Compounds formed between humus and lime, iron and some other elements have strong cementing properties and hence improve the crumb structure of soils, rendering them more friable. The chemical effects on the soil are in part

[1] "Soils," E. W. Hilgard, p. 133.
[2] Bull. 65, Minn. Agr. Exp. Sta.
[3] Bull. 35, No. Dak. Agr. Exp. Sta.

those due to the slow decay of the humus and the liberation of the nitrogen, phosphorus and potassium of the original vegetable matter from which it came.

The nitrogen is especially important and Hilgard[4] says: "Soil humus is doubtless the chief depository of soil nitrogen, and the main source from which, through process of nitrification, the nitrogen supply to plants is usually derived."

The total nitrogen in the soils of the college farm was nearly proportional to the humus and averaged one part of nitrogen to 14.8 parts humus in the clay loam and 1 to 12.8 in the clay.

There is also considerable evidence that humus can unite with some of the compounds used in fertilizing our soils. It has been shown that ammonia salts will combine with humus,[5] the ammonia of the salts replacing lime in the humates.

Similar results have been obtained in this laboratory when potash salts were used instead of ammonia salts. The potash disappeared from solution when humus was added and lime was found instead, showing that the potash must have combined.

It is stated also that humus absorbs monocalcium phosphate,[6] or what is commonly called superphosphate of lime.

It was also noted in our work that nitrates did not seem to leach away in the presence of humus. On three plots used for a top dressing experiment, fertilizers had been applied as follows:

a. 300 lbs. per acre of complete chemical fertilizer, including nitrate of soda.

b. No manure or fertilizer.

c. 300 lbs. per acre of nitrate of soda.

The humus and total nitrogen percentages were:

a. Humus	2.56	Nitrogen	0.18
b. Humus	2.57	Nitrogen	0.16
c. Humus	2.51	Nitrogen	0.20

Experiments are needed to determine whether humus can combine with nitrates as well as with ammonia salts. However, it is more likely to be the fact that by reduction nitrates are

[4] "Soils," p. 135. [5] Hall and Gimingham, Jour. Chem. Soc., 1907, p. 686.
[6] J. Dumont, Exp. Sta. Record, Vol. 13, p. 28.

changed to ammonia and held by the humus, as in the addition of ammonia salts.

The compounds of humus with the soluble superphosphate of lime, ammonia and potash must undergo decompositions similar to those by which the original fertility elements of the humus are made available in the soil. Thus in the presence of humus not only are there plant elements from decaying vegetable matter, but also added fertility elements may be held in a similar condition of availability.

Without the humus, phosphates and potash salts must at length change to the insoluble compounds of those elements naturally present in the soil minerals,[7] while nitrates are leached from the soil by the drainage water.

When these different effects of humus are considered, it can be readily seen how important it is to soils and why sandy loams are regarded as poor soils.

There is a difference of .75 per cent between the sandy loam and the clay loam in the humus, which, calculated on a basis of 3,000,000 pounds of soil per acre-foot, in eight inches would mean 15,000 pounds of humus or 7.5 tons, requiring over twenty-eight tons of stable manure to make it good. The manure is calculated on the basis of its containing 26 per cent of organic matter,[8] not all of which would be humus, and consequently a pound of organic matter in manure would not be equivalent to a pound of humus in the soil.

Such a difference in humus means also a difference in the moisture, nitrogen, phosphoric acid and potash associated with it, which, as has been shown, are in the most surely available forms for plants to use.

Since sandy soils are especially favorable to the destruction of humus, these available forms of plant food change to less soluble forms, or leach away, as the humus decomposes, unless taken up by the crop then on the land. Large dressings of manure therefore have not the lasting effect that is noted on heavier soils, and the same is true of chemical fertilizers. Frequent rotations of crops are especially beneficial on these soils, since

[7] Bull. 30, Bureau of Soils. [8] Bull. 83, N. H. Agr. Exp. Sta.

there is thus added many hundred pounds per acre of vegetable matter in the form of roots and stubble, by the decay of which humus is formed and the texture of the soil and also the chemical composition improved.

The Destruction of Humus.

Humus is not a stable constituent of soils but is modified by the treatment which they receive. All authorities on soils agree that stirring the soil and admitting the air more freely results in a reduction of the proportion of humus.

Hence continuous cropping with hoed crops or letting the land lie fallow will cause a more rapid decrease in humus than where the land is seeded with a crop of rye or oats, and much more rapidly than a soil which is developing a sod. Samples of soil taken in another series of experiments the fall before those already described serve to illustrate these points clearly. The samples were collected at the end of the season in October and in this series were drawn to the depth of 12 inches; hence they cannot be compared with the grass land samples, but only with each other. The soil types represented are the clay and clay loam. On the former soil, the samples represented some tillage and rotation plots which had been under the plow for four years.

One was from a corn plot and one from a fallow plot, both of which had been cultivated throughout the summer, but the fallow plot had been bare, while the other had been covered with a good growth of corn. A rye plot adjacent to the fallow plot and an alfalfa plot completed the list. The rye had been harvested in the summer, the alfalfa was in its first season and had made a fair growth at the time, and the soil had been fairly well shaded by it.

On the clay loam the comparisons were between two vegetable plots in the variety tests, an old abandoned raspberry patch and a crimson clover sod.

The vegetable plots had been well manured with stable manure for three or more seasons, the raspberry plot had been tilled until this season when the last crop of berries had been picked and the plot left until it could be cleared. · The crimson clover

sod was in a plum plot, where it was serving as a cover crop. The percentages of humus follow:

Clay soil.	Rye Plot,	2.37	Fallow plot,	1.36
	Alfalfa plot,	2.83	Corn plot,	1.97
Clay loam.	Clover plot,	2.51	Vegetable plot,	1.85
	Raspberry plot,	2.43	Vegetable plot,	1.60

Fig. 2.— Variety Plum Orchard on Clay Loam.

The average loss of humus due to continuous stirring is .93 per cent on the clay and .74 on the loam. Calculating these differences in pounds per acre to the depth of 12 inches, gives 28,000 pounds of humus in the first case and 22,000 pounds in the second.

On our soils removed generations ago from the virgin condition, it has not been easy to demonstrate clearly that loss of humus necessarily meant loss of productive power.

But in the West it has been possible to demonstrate it, since virgin soils and cropped soils could be directly compared.

In both Minnesota[9] and North Dakota,[10] comparative analyses of virgin soils and wheat soils have shown marked losses in humus. In the former state in eight years of continuous wheat culture, the loss of humus was 17,000 pounds per acre, or over one ton per year. In the latter state old soil cropped for seventeen years continuously was found to contain 1.56 per cent of humus, while new soil showed 2.56 per cent. In another case unbroken prairie contained humus equivalent to 109 tons per

[9] Bull. 70, Minn. Agr. Exp. Sta.
[10] Bulls. 32 and 35, No. Dak. Agr. Exp. Sta.

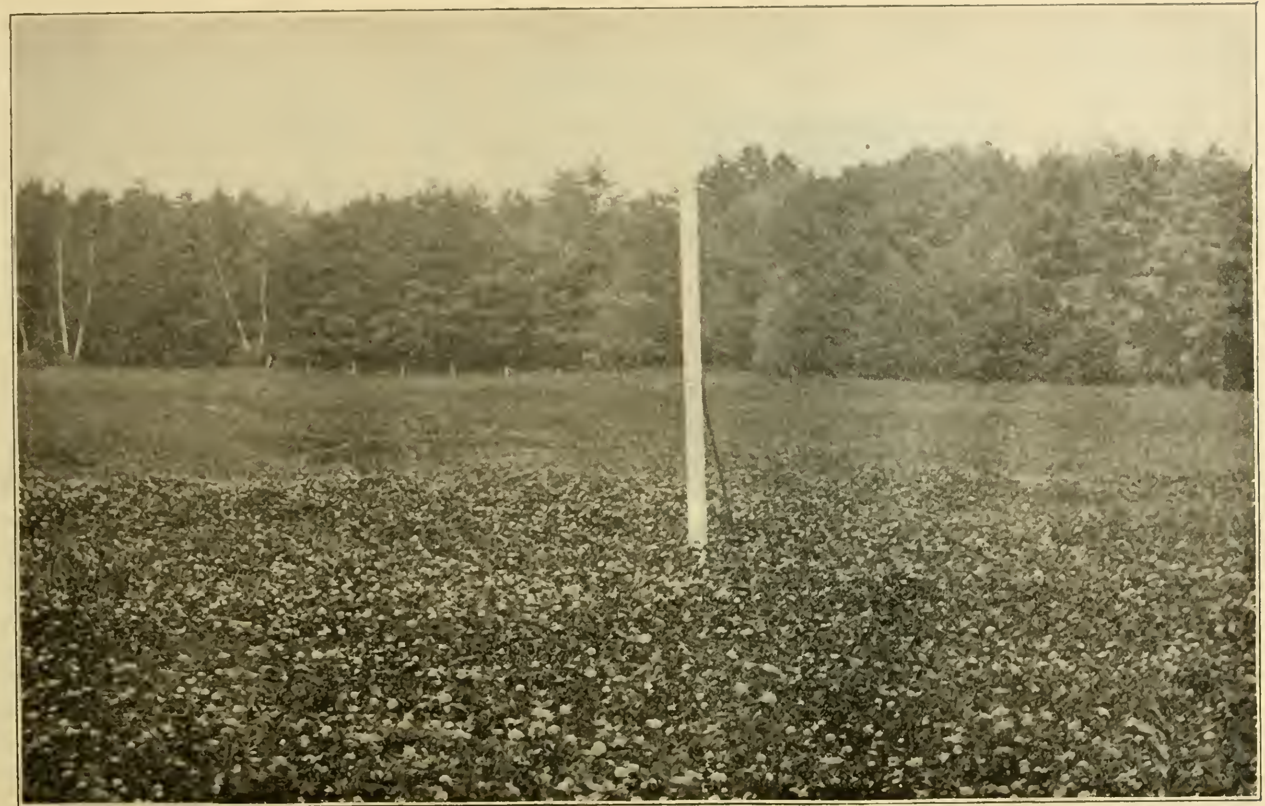

Fig. 3.—Field of alsike and red clover in bloom, on clay soil.

acre, and the soil of an adjacent farm, cropped for fifteen years with wheat, showed sixty-three tons, a shrinkage of 40 per cent.

Our soils shrink in humus relatively faster than this because they contain less organic matter. We have found from 5.5 to 7.5 per cent of volatile matter, while North Dakota reports as high as 15 to 20 per cent. Since all organic matter is not humus but only that portion of it which dissolves in strong ammonia water, a large reserve of organic matter would serve to renew the humus as it was destroyed by tillage, while a small reserve could not maintain it.

Conservation of Humus.

Our analyses and the observations of others show that the saving of humus and its development can be accomplished only by such a rotation of crops that the soil has frequent rests from tillage on the one hand, and the addition of stubble, turf and roots by the plow on the other. The table preceding shows that rest from tillage made a saving of humus equivalent to organic matter in over 50 tons of barnyard manure, when the rye and fallow plots are compared, while liberal dressings could not maintain the humus in the vegetable plots at the level of the adjoining clover sod.

Continuous tillage is not common in this state in general farm practice, but sometimes a field favorably situated is used for a crop of silage corn several years in succession, and it is usually observed that the yields decrease from year to year until the corn crop is given up for another.

On the other hand, a continuous rest from tillage is too common, as grass land is cropped year after year, although the yield may be less than a ton per acre. Humus does not tend to accumulate in grass land but rather to decrease, although not as rapidly as under tillage.

We have found in three samples of old grass land on the clay soil, which had been cropped with hay for more than twenty years, percentages of humus ranging from 2.95 to 3.69 and averaging 3.27, while the average of immediately adjoining fields, which had been under tillage for two years, re-seeded

and cropped with hay for three or four years, was 4.50 per cent. The average difference in humus between these two classes of grass land on the same soil was 1.23 per cent, which, calculated for an acre to the depth of six inches, would be 18,450 pounds, or over nine tons per acre.

The new fields had of course received a dressing of manure at seeding time, but the difference in humus would be equivalent to organic matter in over thirty-five tons of manure per acre, which is more than is ever applied in the practice of the farm. Therefore a considerable part of the gain must have come from the decay of the turf, roots and stubble turned under by the plow.

It is apparent that the marked decrease in the yield of hay after three or four years' cropping is due in part to the decrease in humus and its accompanying fertilizing constituents.

Top dressing with chemicals helps for a time, but at length they fail to yield profitable returns. In fact, their best results have been produced when the field was still comparatively new and before there could have been much decrease in humus.

Available nitrogen is an important element in grass culture and abundant humus will furnish it, provided the soil conditions are favorable to the formation of soluble nitrogen from the insoluble compounds of the humus. By the decrease in humus and the lack of tillage, grass land gradually becomes deficient in available nitrogen, while there may be many pounds per acre locked up in the roots and turf in inactive combinations.

Humus in Wet Clay Soil.

There are many small areas of low wet land which are producing but little on account of poor drainage. Frequently such soils are considered to be muck beds, but usually they are found to consist mainly of clay. They have a high percentage of humus, however, due to the fact that the excess of water hinders its destruction and favors its formation. In two such soils the humus was found to be respectively 6.33 and 6.40 per cent and the total nitrogen was .49 per cent, the ratio of nitrogen to humus being 1 to 13, or practically the same as in our clay soil.

Such soils should be drained, whereupon they would be among our most fertile fields, because of their large amount of latent fertility. They contain about as much humus and nitrogen as the virgin soils of the West, since in North Dakota the maximum humus was reported as 7.9 per cent and nitrogen .45 per cent. With a judicious rotation, the humus could be conserved and the fields maintained for years in a highly productive condition.

It is also probable that these wet soils contain relatively more phosphoric acid and potash available for crops than is found in higher land, because they often receive the drainage of the surrounding slopes.

Therefore it is usually the case that such soils when drained are found to be the most productive of any on the farm.

SUMMARY.

There is a fair average proportion of humus in the soils of this state, and they are by no means worn out when compared with the soils of localities noted for fertility.

It should be the aim of the farmer to increase the proportion of humus in the soil because of its value in relation to soil-water and because it produces a supply of available nitrogen, phosphoric acid and potash.

Continuously tilling the soil on the one hand, or cropping it with hay for a long term of years on the other hand, are unsuitable methods for handling our soils, since the former way destroys humus rapidly, while the latter does not maintain it at the highest point.

A rotation of crops by combining periodical rests from tillage, with additions of sod and stubble to the soil, favors the production of humus and promotes its increase.